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Managing Design and Construction Using Systems Engineering for Use with DOE O 413.3A

[This Guide describes suggested nonmandatory approaches for meeting requirements. Guides are not requirements documents and are not construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]

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1.0 INTRODUCTION

1.1. Goal

The goal of this Guide is to provide the Department of Energy's federal project directors (FPDs) with the knowledge, methodologies, and tools needed to meet Order 413.3A's requirement that they plan, implement and complete their assigned project(s) using a Systems Engineering approach.[1] This requirement is particularly significant because Systems Engineering is the only specific engineering discipline imposed on the FPDs by the Department's directives; and because it provides the FPDs with a methodology that they can use to fulfill the following other responsibilities that DOE O 413.3A imposes on them to:

- demonstrate initiative in incorporating and managing an appropriate level of risk to ensure best value for the government";[2]
- "ensure that safety is fully integrated into design and construction for high-risk; high-hazard, and Hazard Category 1, 2, and 3 nuclear facilities";[3]
- ensure that design, construction, environmental, safety, security, health, and quality comply with the contract, public law, regulations, and Executive orders;[4]
- plan and implement a Quality Assurance Program for the project[5];
- initiate development and implementation of key project documentation;[6] and
- clearly define the roles and responsibilities of the Integrated Project Team relative to the contractor management team.[7]

The intent of this Guide is to provide the FPDs and the Integrated Project Teams (IPTs) with a better understanding of—

- how reports and tasks required by DOE O 413.3A can be brought together as a system,
- how the different DOE O 413.3A guides come together as a system,
- how other DOE rules and directives interface with the project development process, and
- how to use systems engineering lessons learned from past projects.

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[1] Paragraph 6g(2), page 38.
[2] Paragraph 6g, page 38.
[3] Paragraph 6g(13), page 39.
[4] Paragraph 6g(5), page 39.
[5] Paragraph 5k(10), page 31.
[6] Paragraph 6g(3), page 39.
[7] Paragraph 6g, page 38.

These tools, knowledge and insight can help to improve project performance by avoiding systems level integration deficiencies.

1.2. Applicability.

The Guide is applicable to any DOE capital asset acquisition project having a total project cost of $20 million or greater. It may also prove useful to program managers facing similar challenges.

1.3. What is Systems Engineering?

Attachment 3 of DOE O 413.3A, defines Systems Engineering as:

> "A proven, disciplined approach that supports management in clearly defining the mission or problem; managing system functions and requirements; identifying and managing risk; establishing bases for informed decision-making; and verifying products and services meet customer needs"

According to the Order, Systems Engineering is utilized:

- upon approval of mission need to analyze alternative concepts based on user requirements, risks, costs, and other constraints to arrive at a recommended alternative; [8]
- in the Project Definition Phase to integrate requirements analysis, risk identification and analysis, acquisition strategies, and concept exploration to evolve a cost-effective, preferred solution to meet a mission need;[9]
- in the Execution Phase to balance requirements, cost, schedule, and other factors to optimize the design, cost, and capabilities that satisfy the mission need;[10]
- to integrate the design and safety basis;[11] and
- to plan, implement, and complete a project.

1.4. Links with Other Directives

DOE O 420.1B also requires that all DOE federal and contractor elements responsible for design and construction of Hazard Category 1, 2, and 3 nuclear facilities have a Systems Engineering Program[12] that uses configuration management to:

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[8] Paragraph 5c (2), page 5.
[9] Paragraph 5d(2), page 8.
[10] Paragraph 5c(3), page 5
[11] Paragraph 6o(3), page 43
[12] Chapter V for DOE. Attachment 2, Chapter V for contractors.

- develop and maintain consistency among system requirements and performance criteria, documentation, and physical configuration of the structures, systems, and components within the scope of the program;
- integrate the elements of system requirements and performance criteria, system assessments, change control, work control, and documentation control;
- compile and keep current system design basis documentation and supporting documents using formal change control and work control processes;
- identify and consolidate key design documents to support facility safety basis development and documentation;
- periodically assess:
    - the ability to perform design and safety functions,
    - physical configuration for conformity to system documentation, and
    - system and component performance as compared to established performance criteria; and
- test each system after modification to ensure its continued capability to fulfill system requirements.

DOE G 420.1-1, *Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria Guide*, dated 3-28-00, adds the following systems engineering activities relating to nuclear safety:

- identifying and integrating facility nuclear safety requirements,
- coordinating multidisciplinary teamwork in implementing facility safety requirements,
- providing nuclear safety-related interface management,
- providing configuration management to include the establishment of baseline management, and
- coordinating technical reviews of the facility nuclear safety features.

The application of systems engineering to nuclear safety in facility design should be graded commensurate with the facility hazards and complexity. The goal is to ensure that systems engineering activities include consideration of the appropriate facility safety features.[13]

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[13] Paragraph 2.4, page 12.

1.5. Overlapping Systems Engineering and Safety Principles and Practices

Other safety and quality assurance requirements and recommendations in DOE O 413.3A and other DOE rules and directives often overlap with Systems Engineering principles and practices. For example:

- "Missions are translated into work, expectations are set, tasks are identified and prioritized, and resources are allocated." (DOE P 450.4, *Safety Management System*, page 2)
- "Incorporate applicable requirements and design bases in design work and design changes." [10 CFR 830.122, Section (f)(2) and DOE O 414.1C, *Quality Assurance*, paragraph 4f(2)]
- "Applicable standards and requirements are identified and agreed-upon, controls to prevent/mitigate hazards are identified, the safety envelope is established, and controls are implemented." (DOE P 450.4, *Safety Management System*, page 3)
- "Resources shall be effectively allocated to address safety, programmatic, and operational considerations. Protecting the public, the workers, and the environment shall be a priority whenever activities are planned and performed." (DOE P 450.4, *Safety Management System*, page 2)
- "Competence commensurate with Responsibility - Personnel shall possess the experience, knowledge, skills, and abilities necessary to discharge their responsibilities" [DOE P 450.4, *Safety Management System*, page 2) and DOE O 413.3A, paragraph 5k(6)(c)]
- "Identify and control design interfaces." [10 CFR 830.122, Section (f)(3) and DOE O 414.1C, *Quality Assurance*, paragraph 4f(1)]
- Ensure "effective communication among all project stakeholders." (DOE O 413.3A, paragraph 5a)
- "Risk Management is an essential element of every project. The DOE risk management approach must be analytical, forward looking, structured, informative, and continuous. Risk assessments are started as early in the project life cycle as possible and should identify critical technical, performance, schedule, and cost risks." [DOE O 413.3A, paragraph 5k(11)]
- "Verify/validate work before approval and implementation of the design." [DOE O 414.1C, *Quality Assurance*, paragraph 4f(5)]
- "Verify/validate the adequacy of design products using individuals or groups other than those who performed the work." [10 CFR 830.122, Section (f)(4) and DOE O 414.1C, *Quality Assurance*, paragraph 4f(4)]

Additional embedded materials and linkages are identified in Attachments 2, 3, 4 and 5.

Some requirements do not specify a point in a project by which they should be met. This Guide addresses those points at which compliance should be attained.

1.6. Differences in Terminology

Functional requirements and performance requirements are defined differently and have significantly different contexts from domain to domain and in different Departmental directives. These differences will be pointed out, where possible, to avoid confusion.

1.7. How this Guide is Structured

The Guide's structure mirrors the project evolution process outlined in DOE O 413.3A and the above definitions of Systems Engineering to the extent possible. Specific actions that should be taken at each step in the project evolution are addressed in separate sections in the approximate sequence in which it would be performed; however, it should be recognized that many of the actions are iterative in nature and should be undertaken in parallel and would have to be undertaken in a different sequence if an architect-engineer is utilized to develop the alternative design concepts. Issues such as verifying that products and services meet customers’ needs that are integral to each step of the project evolution process are, by necessity, addressed in increments as they emerge.

Unlike the other 413-series Guides, this one begins from a higher level starting point to look at how all DOE directives (i.e., the various components that comprise DOE's management system) come together as a project evolves.

The FPD and the IPT roles and responsibilities for design and construction management are addressed with attention placed on the front-end of a project since the Department, as owner is responsible for defining the mission and the associated requirements; obtaining the human, financial, and technical capabilities needed to meets those requirements; and planning the project so as to deliver the greatest net value.

1.8. Sources of Information

The Guide presents acceptable methods for implementing the Systems Engineering requirements specified in DOE O 413.3A together with supplemental information about these methods including lessons learned. This information flows from other Government agencies’ procedures; professional societies' presentations and publications; national and international consensus standards; texts; doctorate dissertations; and, lessons learned from independent reviews and research studies of failed or troubled projects.

The quality and quantity of the research in the field has promoted an extensive evolution of Systems Engineering in the past decade. Principles and practices that are new include attention to interdependency and uncertainty management.

2.0 ASSEMBLE AND CHARTER THE INTEGRATED PROJECT TEAM

IPT assembly and chartering is one of the first actions taken on a project because the IPT performs the bulk of the activities in the project definition phase (i.e., the phase between Critical Decision 0 and Critical Decision 1). DOE O 413.3A specifies four separate requirements in regards to the assembly and chartering of the IPT. Specifically:

- FPDs clearly define IPT roles and responsibilities relative to the contractor management team[14]
- The Charter specifies IPT decision making authority.[15]
- The Charter provides the IPT's operating guidance.[16]
- "Competence (shall be) commensurate with Responsibility - Personnel shall possess the experience, knowledge, skills and abilities necessary to discharge their responsibilities."[17]

The actions associated with these four requirements are frequently interdependent and should be considered and responded to in toto.

Responsibility for assembly of the IPT and the development of the Charter depends upon whether an FPD has been appointed. The program manager or the head of the field organizations establishes the IPT and prepares the initial Charter if a permanent FPD has not been approved. These same individuals formally concur with the Charter if a permanent FPD has been approved because the bulk of the project's staffing will be taken from their organizations. IPT assignments on larger projects typically require all, or nearly all, of the IPT member's time and can last for several years. Both IPT membership and the Charter must be approved by the Secretarial Acquisition Executive or the Acquisition Executive.[18] The Secretarial Acquisition Executive or the acquisition executive should evaluate whether the proposed staffing is adequate for the complexity and importance of the project before approving these documents.

On more complex projects, the Charter and the IPT staffing plan are likely to be modified and re-approved several times over the course of the project to accommodate membership needs and activities the IPT should perform. Updates and new requests for approval should be integrated with the Critical Decision approval process.

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[14] DOE O 413.3A, paragraph 6g, page 38.
[15] DOE O 413.3A, paragraph 6g(10), page 39.
[16] DOE O 413.3A, paragraph 6g(11), page 39.
[17] DOE O 413.3A, paragraph 5k(6)(c) and DOE P 450.4, page 2.
[18] DOE O 413.3A, Table 2, page 12.

3.0 PRE- CONCEPTUAL PLANNING

Pre-conceptual or up-front planning is initiated as either the final activity prior to Critical Decision 0 or the first activity immediately after[19] Critical Decision 0 approval and is the beginning of systems engineering. This multifaceted effort entails simultaneously defining the end product the project will deliver and how the design and construction activities will be undertaken and managed. Both efforts are tightly intertwined. The precise method of undertaking and managing the design and construction efforts depends upon the end product. And, conversely, the end product has to be compatible with what the designers, constructers, and management teams are actually capable of delivering successfully.

The FPD[20] and the IPT perform the bulk of pre-conceptual planning and ensure that the two efforts are aligned through a series of iterative steps starting with capturing the project requirements and ending with determining the appropriate project development strategies.

Each of these steps is defined below together with the specific action(s) that should be taken at the completion of the step.

3.1. Capture Project Requirements

Identifying project requirements is fundamental to systems engineering and is integral to or a prerequisite for nearly all of the tasks identified in DOE O 413.3A. It is impossible to develop a meaningful Risk Management Plan, Project Execution Plan, Acquisition Strategy, or the alternative design concepts needed for Critical Decision 1 approval without previously identifying the requirements associated with the project. Similarly, the probability of the architect and engineering firms' developing an acceptable design solution or the necessary depth of specifications and drawings are nil if they do not know the Department's requirements.

Project requirements are the primary means of communicating the Department's expectations to the organizational elements involved in the project. Accordingly, they should enfold all of the major aspects of the project, provide the depth of information each user needs to perform their particular role, and be available for the user at the right point in time.

3.1.1. Enfold All Major Aspects of the Project

Project requirements fall into two categories. The first is comprised of those attributes that the project is expected to demonstrate once it is completed (e.g., mission related requirements such as storage capacity and production rates, operational requirements such as mean-time-to-failure, and requirements that are adjunct to the mission but of major importance such as safety and security).

The second category is comprised of procedural requirements the deal solely with project delivery (e.g., calculation methods, reports and data to be developed and submitted at specific

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[19] NNSA requires that a Program Requirements Document be included as part of the Critical Design 0 approval package.

[20] The program manager or the head of the field organization may be serving the FPD at this point in the project.

stages, approvals that must be received, codes and standards to meet, mandatory reviews, and specific design approaches.

Both categories can be fully defined only by:

- identifying all of the project stakeholders and their expectations, priorities and values;
- identifying the laws, rules, directives, and standards with which the project must comply; and
- working backward from the project mission and other end goals.

3.1.1.1. Project End Product

The Mission Need Statement is the starting point when capturing requirements related to the end product of the project in that it "translates an identified performance gap into functional requirements that cannot be met though other than material means."[21] The Mission Need Statement generally addresses only one or two aspects of mission related requirements and does not provide enough information to allow a valid comparison of alternative conceptual approaches. Additional information is needed on the operational and life cycle aspects of the mission including:

- quality;
- processing;
- operability;
- reliability/dependability;
- maintainability and reparability;
- availability;
- flexibility, agility, adaptability, upgradeability;
- survivability;
- durability;
- adaptability;
- decommissioning, deconability and disposition,
- sustainability;

[21] DOE O 413.3A, paragraph 5d(1), page 7.

- survivability; and
- testability.

These topics are most readily determined by seeking input from stakeholders that will use or be impacted by the project and undertaking a function analysis of the mission. Internal functions most frequently impacted by the project include management and operating contractors' safety, environmental, and health; security; maintenance; utility or plant; and transportation organizations. External organizations likely to be impacted by the project are generally the same as internal organizations and include both state and local governments.

The identification of such operational and life cycle requirements is particularly important when there is not an accepted industry-wide norm to utilize in the absence of definitive information. Much of the "requirement creep" on projects can be traced to a failure to capture operational and life cycle requirements.

3.1.1.2. Adjunct Goals and Recommendations

Adjunct areas of focus such as safety, environmental protection, security, contracting, value management, and energy efficiency have mandatory goals and requirements, and non-mandatory design and procedural preferences to be folded into both the final product and the project delivery process. Many objectives and requirements associated with adjunct areas are defined in government rules, policies and regulations; DOE directives and standards; and, contract terms and conditions. For example:

3.1.1.2.1. Quality Assurance

DOE G 414.1-2A, *Quality Assurance Management System*, sets forth the following recommendations pertaining to design:

- "A design process should be established that provides appropriate control of design inputs, outputs, verification, configuration and design changes, and technical and administrative interfaces."
- "The design of systems, structures, and components; software; and processes should be subject to design process controls and verification requirements appropriate to the level of risk the item presents to the public, the environment, and project success."
- "Designs should provide for appropriate acceptance, inspection, testing, and maintenance criteria to ensure continuing reliability and safety of the items."
- "The designer should consider the expected use and life expectancy of the items to allow appropriate disassembly and disposal requirements to be addressed."
- "Aspects critical to the performance, safety, or reliability of the designed items should be identified during the design phase."

3.1.1.2.2. Safeguards and Security

DOE G 413.3-3, *Safeguards and Security for Program and Project Management*, indicates that the following should be developed during the project definition stage:

- threat assessment,
- materials control and accountability,
- physical security,
- information security,
- personnel security,
- cyber security,
- barriers,
- access controls,
- explosives, and
- communication.

3.1.1.2.3. Fire Protection

DOE O 420.1B, *Facility Safety*, establishes fire protection design requirements pertaining to:

- water supplies,
- noncombustible construction materials,
- fire-rated construction and barriers, including penetration sealants,
- automatic fire extinguishing systems,
- redundant fire protection systems,
- the separation of redundant safety class systems,
- fire alarm and signaling systems,
- emergency egress and illumination,
- physical access and standpipes for fire department intervention,
- prevention of accidental release of contaminated products of combustion and fire fighting water, and

- fire protection and safety system interfaces.

DOE Standard (DOE-STD) 1189, *Integration of Safety into the Design Process*, states:

- A Fire Hazards Analysis (FHA) is required for all Hazard Category 1, 2, and 3 nuclear facilities or facilities that present unique or significant fire risks. A FHA requires a comprehensive evaluation of fire hazards, including postulation of fire accident scenarios and estimates of potential consequences (i.e., maximum credible fire loss).

- "In the conceptual design, a preliminary FHA provides fire protection strategy alternatives for control or mitigation of accident consequences. Fire protection strategies will dictate design requirement."

- "For designs that do not comply with appropriate NFPA Standards, Authority Having Jurisdiction (AHJ) review and acceptance of design outputs relevant to fire protection and life safety are required. Appropriate interfaces with the AHJ should be anticipated and planned."

DOE G 420.1-3, *Implementation Guide for DOE Fire Protection and Emergency Services Programs for Use with DOE O 420.1B, Facility Management*, defines acceptable methods to implement the fire protection requirements in DOE O 420.1B, including:

- fire protection designs,
- water supplies,
- automatic fire suppression,
- fire suppression system confinement or containment,
- fire protection system classifications, and
- the NEPA codes and standards likely to be applicable.

DOE-STD-1066-99, *Fire Protection Design Criteria*, provides guidance on:

- water supply and distribution systems,
- automatic sprinkler systems,
- fire alarm systems,
- structural fire protection,
- life safety,
- electrical equipment,

- general process hazard fire protection,
- special hazards,
- nuclear filter plenum fire protection, and
- glovebox fire protection.

DOE O 440.1B, *Worker Protection Program for DOE (including National Nuclear Security Administration) Federal Employees* provides requirements on:

- What constitutes an acceptable fire protection program.
- Life safety codes.

3.1.1.2.4. Sustainability

DOE O 430.2B, *Departmental Energy, Renewable Energy and Transportation Management,* requires that capital asset construction or major renovation projects:

- Attain U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) Gold certification.
- Incorporate the Guiding Principles of Executive Order 13423.
- Incorporate renewable energy equipment into building design to the maximum extent feasible.

3.1.1.2.5. Value Engineering

DOE O 430.1B, *Real Property Asset Management*:

- Requires that the contractor use value engineering techniques in a tailored manner to reduce DOE's real property asset ownership costs (e.g., acquisition, operations, maintenance, and disposal) while maintaining the necessary level of performance and safety.
- Invokes the requirements contained in[22]
    - Office of Management and Budget Circular A-131, *Value Engineering.*
    - P.L. 104-106, Section 4306, *Value Engineering for Federal Agencies.*

[22] DOE P 413.3.2 similarly invokes Public Law (P.L.) 104-106 and OMB Circular A-131

- ASTM Practice 1699.00, *Standard Practice for Performing Value Analysis for Buildings and Building Systems.*

3.1.1.3. Project Delivery Procedures

Procedural requirements defining how the project is to be developed are found in the same source documents as the adjunct goals. It is generally not enough; however, to just state that the project should be developed in accordance with these source documents. A good share of the compliance problems that are surfaced during the various project reviews can be traced to a simple lack of awareness of procedural requirements. While reviews correct this lack of awareness, downstream corrections are always more costly than ensuring that the performing parties have a full understanding of the requirement before starting work. One of the keys to project success is the degree to which the procedural requirements can be clearly linked to the specific tasks to be performed in each project phase.

The establishment of such linkages is complicated by the fact that many of the procedural requirements contained in the source documents are situational in nature and only come into play if a particular condition is found to exist as the project unfolds. This is particularly significant from a project planning and management standpoint since both the information needed to determine if the triggering condition exists and the actual determination typically resides outside of the functional disciple/organizational element that is undertaking the impacted design. This creates an interdependence that can have a major impact on the manner in which the project is executed. Such interdependence is discussed in section 3.4.2.2.4.3.

3.2. Concurrent with Requirements Capture

A number of different activities should be performed concurrently with the requirements identification process just described. These activities are described below.

3.2.1. Determine the Depth to Which the Requirements Are Defined

Requirements at front-end of the project are typically defined to one of the following three increasing depths.

3.2.1.1. Performance Issues

Performance applies to end result but not the means, the processes or procedures by which it can be achieved. Performance requirements provide great latitude for innovation but only minimum bases for either the Department or contractors to estimate project scope, cost, and schedule. Even more important, they typically do not provide a measuring stick for determining progress or the acceptability of the end result.

3.2.1.2. Functional Issues

Functional requirements have varied definitions in DOE directives and are in most cases sub-elements that have the same two basic limitations as performance requirements in that they normally do not provide a measuring stick for progress assessment or a means of determining the acceptability of the final product.

3.2.1.3. Detailed or Procedural Issues

Detailed requirements or procedural requirements focus as much on how work is to be performed, as what is to be produced. They can appear in different forms including Departmental and consensus standards, design criteria, and state and local codes.

3.2.2. Determine if the Depth of Definition Is Adequate and Address Any Gaps

There are two opposing perspectives regarding the depth to which project requirements (end product and adjunct requirements) should be refined. The first is based on the premise that detailed requirements will overly constrain the private sector (the architect/engineering firms, the equipment suppliers, and the constructors) who should do the work and will result in higher project costs. The second perspective is based on the premise that detailed requirements are the only way of ensuring that the end product will perform as needed and are, therefore, essential.

The situation determines which of these two perspectives is correct . Detailed requirements are normally not warranted on projects that can be successfully delivered using proven designs and commercially available components or systems. They are warranted and are in some cases essential:

- on atypical projects that are pushing the state of art;
- when confronted with high risk environments/missions;
- when needed to ensure that individual designers will produce the correct end product. (Highly capable designers do not need detailed requirements. Designers that do not have extensive knowledge and experience, however, do need prescriptive requirements.); and
- when it is questionable whether the necessary level of fabrication, or construction experience is available in the market place.

These situations are common on Hazard Category 1, 2, or 3 nuclear facilities. Experienced with design breakage, construction rework, and technical disputes suggest a need for deeper levels of requirements. Some of the sub-areas that have proven particularly troublesome are listed in Attachment 1.

The FPD and the IPT should decide, at this point in pre-conceptual planning, what depth of refinement is appropriate in each of the listed sub-areas and address any gaps when evaluating conceptual alternatives, developing acquisition strategy, writing the project execution risk management plans, identifying tasks that should be completed prior to initiation of preliminary design, and scoping the project execution phase.

Design criteria constitute the deepest level of refinement normally justified at this stage of project development. Dedicated writing teams composed of true subject matter experts from the government, the management and operating contractor and the private sector are essential when developing design criteria level requirements. Architect/engineering firm personnel who will be executing the design should also be included on the writing team, if at all possible.

3.2.3. Identify and Address Any Missing Requirements

While the list of operational requirements that have been extracted from the mission stakeholders and the list of procedural requirements extracted from the adjunct stakeholders and the Department's directives may appear all inclusive, it is inevitable that some critical requirements were either overlooked or could not be ascertained. Operating requirements typically prove to be extremely difficult to define.

Both DOE and management and operating contractor organizations are built around specific missions and adjunct goals such as safety, security, environmental protection, procurement, etc. The spokespersons or champions for these areas are easily identifiable and can generally supply a fairly complete list of their procedural requirements. They are generally less able to define how requirements are likely to change before the project has been completed; i.e., the importance of maintaining flexibility. Even more important, it is normally difficult, if not impossible, to find an individual that understands all the site wide needs and uncertainties and can translate these into project level operating and flexibility requirements.

The FPD and the IPT need to determine the potential consequences the missing and/or unstable requirements may have on the project and factor their conclusions into the Risk Management Plan, the Project Execution Plan, the Acquisition Strategy, the evaluation of conceptual alternatives, and the list of activities that should be performed prior to the initiation of preliminary design.

3.2.4. Identify and Address Technology and/or Design Solution Limitations

New technologies, new material applications, and/or new design concepts may be necessary to satisfy an end product requirement on projects that are "pushing the bubble" or may be desired on more conventional projects to improve efficiency. Technology readiness level (TRL) analyses should be utilized when comparing requirements against available technical capabilities, material applications, and currently available design solutions. The TRL encompasses key factors such as scale-up and operating environment that are applicable to both of these constraints.

The acceptability of a TRL depends upon:

- how critical the system is to mission success or safety;
- the probability that the technology will prove successful;
- the availability of a proven backup technology or design concept that can be substituted if the new technology or design solution cannot be elevated to TRL 5 or higher by Critical Decisions 2; and

- the cost, schedule, and performance penalty that will be incurred if the backup solution should be utilized.

A TRL of less than 3 at the pre-conceptual stage of a project normally warrants management scrutiny.

The potential impact of a technology gap on a project is, in many ways, greater than on a program because project design is performed under an Architect-Engineer Services contract while the maturation and demonstration of the new technology would normally be performed by either the M&O or a totally separate contractor. This introduces yet another coordination complexity.

3.2.5. Identify and Address Market Related Limitations

Analytical tools, properly qualified engineering and construction forces, and materials will be needed to meet the requirements. The availability of these items should be taken into consideration when planning the project. Failing to recognize a lack of availability in any of these areas can result in reduced downstream competition with accompanying higher cost for the government, quality problems, and longer schedules.

This initial determination of available capabilities will serve as a forerunner for the more rigorous individual evaluations that the Federal Acquisition Regulations (FAR) require for architect/engineering services and should focus on the same areas as those evaluations. These include:

- "Specialized experience and technical competence in the type of work required …"
- "Past performance on contracts with Government agencies and private industry…"[23]

The FAR's position regarding discussions with potential suppliers has changed in recent years. The December 2007 edition now states:

> "Potential offerors should be given an opportunity to comment on agency requirements or to recommend application and tailoring of requirements documents and alternative approaches. Requiring agencies should apply specifications, standards, and related documents initially for guidance only, making final decisions on the application and tailoring of these documents as a product of the design and development process. Requiring agencies should not dictate detailed design solutions prematurely."[24]

This change provides an opportunity for an improved understanding of market constraints.

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[23] Federal Acquisition Regulations, Subpart 36.602-1.
[24] Federal Acquisition Regulations, Subpart 11.002.

3.2.6. Identify and Address Internal Staffing Limitations

DOE and the M&O contractors staffing limitations result from the aging of the work force and the decline of the nuclear power industry over the past three decades. These limitations are particularly severe in regards to certain individual requirements and are highlighted in numerous reports. Heavy workload demands and staff shortages make it difficult to assume that in-house M&O staffing will be available just because it may be present somewhere in the M&O contractor's organization. Possible methods of compensating for internal staffing limitations are addressed later in the Guide as part of a broader discussion.

3.3. Determine the Net Effect of Individual Requirements

The challenge of meeting a requirement can change dramatically when it is seen as part of a total set of requirements that must be satisfied. What may have been simple can become complex and the complexity of the development effort has a direct bearing on both the levels of skills that will be needed to successfully undertake the project and the type of tools and procedures that should be used. The greater the complexity, the higher the skill levels needed. While there is not a universally accepted method of dividing complexity into its various sub-elements or translating complexity into cost and schedule estimates, the following breakout provides enough of a yardstick to support parametric comparisons and should be used as a starting point.

3.3.1. Physical Complexity

Physical or detail complexity is a reflection of the number of components and number of networks that link them together. Projects involving many different goals, requirements, constraints, stakeholders, organizations, individuals, technologies, or components are probably physically complex. Physical complexity cannot, however, be determined simply by adding up numbers. The physical complexity of a facility composed of 1,000 different components may, for example, be greater from a designer perspective than the physical complexity of a facility composed of four identical assembly lines each composed of 500 components even though the latter contains twice the total number of components.

Numbers can be particularly misleading in the case of organizational elements. Most senior FPD are, for example, capable of successfully overseeing and communicating with seven directly reporting sub-organizations. The FPD's level of their success will, however, decline sharply if those organizations are vertically stacked as descending levels subcontractors. Both downward and upward communications will be reinterpreted at each organizational boundary it passes through and will soon take on a totally different content and meaning than originally intended.

Similarly, physical complexity can increase nearly exponentially once an individual's or an organization's limits are reached. The challenge of coordinating 30 different contractors is far more than twice as difficult as coordinating 15 different contractors; a fact that has contributed to many project problems.

3.3.2. Combinatorial Complexity

The degree to which the different goals, requirements, organizations, individuals, technologies, and components can be aligned can have an even greater bearing on staffing skill levels than the physical complexity of the project since misalignments make it more difficult to arrive at a mutually acceptable solution.

DOE has experienced particular difficulties when attempting to combine competing schedule and safety goals. DOE's formal process of extensive checks and balances focuses on ensuring the safety of nuclear projects. This process cannot be easily shortened or accelerated to meet schedule objectives.

Safety also appears as a combinatorial complexity element at lower levels of the project. The most common means of satisfying occupant life safety requirements for egress is, for example, to provide multiple fire exit doors directly out of the building. This design solution is fine for office or warehouse facilities, but directly conflicts with the security and contamination control necessary when a building contains nuclear materials. The likelihood of such negative linkages increases as the number of requirements increase. Some negative linkages can be resolved by using more sophisticated design approaches provided they are recognized and clearly identified as one of the challenges that designers address.

Combinational complexity can also be increased by the following:

3.3.2.1. Funding

Nearly every project is bound by some level of budgetary constraints. These constraints can add significant complexity and often even prove to be incompatible with the requirements. Failure to acknowledge the full impact of funding induced complexity inevitably leads to unrealistic plans and expectations.

3.3.2.2. The Site

Few DOE projects are self-supporting, "green-field" undertakings. Most fit within constrained physical spaces and utilize already existing site utilities and services. Also, there are typically very specific access and interface issues that should be taken into consideration at every phase of the project. This is particularly true in the case of projects in security areas and/or modifications of operational facilities that may contain hazardous materials.

3.3.2.3. Government Policies

Federal and state policies impose a number of constraints, and therefore complexity, that the private sector does not have to experience. These need to be understood by those charged with designing the project. Policies relating to small business utilization and Buy American Act are, for example, unique to Federal projects and should be made visible so that they can be taken into consideration during the planning process.

3.3.3. Dynamic Complexity

Dynamic complexity always involves some aspect of time. In appears in its simplest form as volatile or unstable conditions that change over the course of the project or even between Critical Decisions. Project requirements, funding, and personnel/staffing have shown a historic tendency to fluctuate over relatively short periods on past DOE projects and are recognized contributors to dynamic complexity. Projects that are experiencing this form of dynamic complexity are not yet ready to be baselined.

At the employee level, the amount of time needed to perform an activity is the most common form of dynamic complexity. Tasks that an individual can successfully perform given adequate time become dynamically complex for the same individual when they are to be performed in short periods of time.

The most common form of dynamic complexity at the group level is informational independence. Structural engineers cannot, for example, design a processing bay or cell roof unless process engineers tell them the distances they will have to span to accommodate the necessary processing lines. The process engineers cannot, in turn, size the processing lines until they know the throughput rates to be achieved, maintenance constraints, the operating environment, etc. Dynamic complexity, on complex projects, can increase to the point that conventional schedule tools lose their effectiveness.

A fourth, and significant different, facet of dynamic complexity is how easy or difficult it is for an individual employee or an organization to recognize and understand the cause and effect relationships that occur over the life span of a project. Effects that are widely separated in time and space from their causes are more dynamically complex that those that occur in close time proximity. Dynamically complex projects place greater cognitive demands on the senior members of the project team.

3.3.4. Evaluative Complexity

Evaluative complexity is a measure of how easy it is to determine if an objective is being met over the course of the project. The evaluative complexity of a particular requirement will normally be different at each Critical Decision point.

3.4. Risk Informed Planning to Set Strategic Direction

The FPD and the IPT should have an adequate understanding of the situation to undertake an integrated set of risk informed actions that will set the overall course of the project. These risk informed actions differ from those normally described in the Project Risk Management Plan in a very significant way. While the Risk Management Plans focus on how specific events would impact the already developed project plan if they were to occur; pre-conceptual risk management reverses this perspective, and focuses on how the project should be planned to avoid or minimize the various risks (i.e., constraints, challenges, or uncertainties) that are either known or are likely to surface (based on lessons learned from similar undertakings) as the project evolves. This reversed way of thinking is, in effect, the ultimate form of proactive management and provides a far broader range of opinions.

3.4.1. Determine if Necessary Skill Levels Are Obtainable

As can be seen from the earlier sections, project feasibility hinges on the experience, knowledge, skills, and ability and contractor personnel necessary to simultaneously meet project goals and handle delivery risks (constraints, challenges, and uncertainties). The FPD and the IPT should therefore:

- Identify the number personnel with specific experience, knowledge, skills, and abilities needed at each stage of the project.
- Link these needs with the individual requirements and risks to the extent possible.
- Determine the current and future availability of personnel and contractors.
- Package this information in the form of a Project Staffing Plan that can be incorporated into the Project Execution Plan, the Acquisition Strategy, and the Risk Management Plan.

If major gaps surface between project needs and the availability of qualified personnel the FPD and the IPT should:

- Adjust discretionary requirements downward.
- Adjust the delivery risks downward.
- Use collaborative organizational structures or other techniques to broaden the pool of available resources beyond that obtainable from a single operations office or contractor.
- Upgrade the obtainable experience, knowledge, skills, and abilities of the individuals or organizations.

Each of these alternatives is addressed below.

3.4.1.1. Adjust Discretionary Requirements Downward

Although adjusting the project's discretionary requirements downward to the capability level of the project is the surest, most cost effective means of correcting a capability gap, it is, often resisted by those advocating the discretionary requirements. Such resistance can often be resolved by verifying the requirement's link to the mission need or an adjunct goal and then performing a cost/benefit analysis. The results of these two efforts should be formally documented and made available to both the advocate and the Acquisition Executive.

3.4.1.2. Reduce Project Delivery Risks

A number of tools and techniques can be used to reduce project delivery risks as follows.

3.4.1.2.1. Benchmarking and Lessons Learned

An easy and reliable method of reducing uncertainties regarding the cost, schedule, and technical feasibility of the project at the pre-conceptual stage of development is benchmarking. Benchmarking involves determining the actual cost, schedule, and performance levels of similar projects (or systems) that have already been completed and then adjusting the data from those projects to compensate for any differences in scale, location, market conditions, etc. using parametric techniques.

Identifying a pool of similar projects to use as a benchmark offers a secondary benefit in that this pool of already completed projects can also serve as a source of lessons learned. The inability to find any similar projects to serve as benchmarks should be seen as a danger sign that we are attempting to push beyond the state of the practice and should expect the high level of difficulties and risks that come with a first-of-a-kind effort.

3.4.1.2.2. Collect/Generate Missing Knowledge

All projects begin with incomplete information and unverified assumptions. The benchmarking and lessons learned processes should provide some insight as to the relative importance of the missing information and unverified assumptions and allow the FPD and the IPT to determine which of the missing elements are the most critical to the conceptual effort and should, therefore, be addressed first.

The process of collecting and/or generating the missing or incomplete knowledge is, in essence, a mini project. A formal data base should be developed that identifies each uncertainty. The specific methods that will be used to obtain the knowledge should be laid out. Necessary quality levels should be defined and resources should be obtained. Schedules should be developed based on foreseen need dates and the level of importance of the missing information to the project development process. And, progress should be tracked and managed.

While the process of collecting missing information is straight forward, it is not always possible to fill in all the blanks, particularly in regards to the quality and reliability of the knowledge that can be obtained regarding elements such as political constraints and future funding available. These limitations can be partially addressed through the use of the project development strategies discussed in section 3.4.2.

3.4.1.2.3. Use a Collaborative Organizational Structure

Needed knowledge, skills, and experience levels can be obtained through the use of joint ventures or partnerships that bring together organizations with complementary skill mixes. Many of the Department's M&O contractors were formed using collaborative organizational concepts. Collaborative organizational structures have also been used to increase available funding and/or knowledge on some of Department's larger individual projects.

While collaborative organizational structures can reduce skill related risks they almost always add offsetting combinatorial complexity and have been the source of some high profile project failures. They should be approached with caution.

3.4.1.2.4. Upgrade Federal and/or M&O Skill Levels

It is possible, under some conditions, to fill skill gaps through individual and/or team training, which is most effective when tailored to specific project needs and delivered at the specific time of need.

3.4.2. Determine the Appropriate Project Development Strategies

A variety of project development strategies are available; but each is only appropriate for a particular set of circumstances. Selection of an appropriate strategy can decrease the risk of project failure, while selection of an inappropriate strategy can significantly increase the risk of failure. The general factors that determine which strategy is the most appropriate follow:

- the completeness and accuracy to which requirements can be defined;
- the compatibility of the requirements;
- the constraints;
- the complexity of the project;
    - what is known and what is unknown; and,
    - the knowledge, skills, and abilities of both the organizations and the individual project participants.

Further information is provided below.

3.4.2.1. Select the Appropriate Overarching Strategies

Two different overarching strategies are widely used outside of DOE. They are:

3.4.2.1.1. "Waterfall" Development

The "waterfall" strategy is a traditional approach that consists of defining the mission and adjunct requirements; producing the drawings and specifications that satisfy the requirements, and constructing a facility and/or process in compliance with the drawings and specifications. This strategy is straightforward and automatically selected by most project participants, however, it is optimal only when:

- The requirements can be clearly understood by all project participants, are unlikely to change during the development process, and accurately reflect the owner's or stakeholder's expectations.
- There are no significant uncertainties or risks associated with either the project delivery process or satisfying the requirements; i.e., there are no insurmountable staff, schedule, budgetary, or technology constraints.

- The project is being undertaken in a stable and predicable environment.
- The project is not overly complex.
- The Department is willing to limit its level of post Critical Decision 1 involvement to oversight.

3.4.2.1.2. Evolutional Development

The benefits of using evolutional development strategies became apparent in the 1990's following root cause analysis of cost, schedule, and performance problems in software development. Two different forms of evolutional development are now generally recognized as being preferable for higher complexity, higher risk projects. They are:

3.4.2.1.2.1. Spiral Development

A spiral development approach is appropriate when the desired project outcome can be stated but associated requirements cannot be defined. The development process is undertaken in a series of short exploratory cycles with each cycle designed to:

- provide clearer definition of the requirements,
- obtain better understanding of the associated risks,
- determine if the risks are resolvable, and
- clarify the path forward. Individual aspect of the projects can be explored concurrently rather than sequentially during the early stages of exploration.

The FPD and the IPT determine the specific objectives and scope of each cycle based on risk importance. They then evaluate the information obtained from the cycle and determine the cost/benefits of pursuing additional cycles. The option of recommending that the development effort be halted or totally redirected is available at the end of every cycle.

3.4.2.1.2.2. Incremental Development

An incremental development is selected when:

- The requirements associated with the outcome can be defined but do not appear immediately achievable because of technology, engineering, or funding constraints.
- Having an operational project that partially satisfies owner and stakeholder expectations is more desirable from a cost/benefit standpoint than not having or delaying the project until the necessary capabilities become available.

The project is specifically designed with adequate flexibility to allow future upgrades. Incremental development is inherently a risk avoidance or mitigation approach. It may be the only viable approach when faced with schedule pressures or significant staffing, budgetary, knowledge, or technology constraints.

3.4.2.2. Select Appropriate Sublevel Strategies

Sublevel strategies are available for use with either of the of the evolutionary development strategies or in advance of implementing a waterfall strategy. These are summarized below.

3.4.2.2.1. Strategies for Resolving Requirements Uncertainties and Unknowns

Most stakeholders cannot clearly state what their requirements are, or identify all of their requirements. The following five strategies or tools are available to help both situations.

3.4.2.2.1.1. <u>Design Charettes</u>

Architects have long utilized design charettes for several hundred years by as a means of understanding client needs and preferences. Clients and the architectural team hold face-to-face meetings during which the architects pursue specific lines of inquiry and generate on-the-spot sketches reflecting what they believe the client is requesting. These sketches are utilized to iteratively clarify the client's priorities.

3.4.2.2.1.2. <u>Prototypes/Models</u>

Prototypes and models are typically utilized to test new components or unproven design concepts but, can also be used as follow-on to design charettes to help occupants and maintenance forces discover unrecognized requirements and loosen overly restrictive requirements by providing a means to test drive alternative design solutions. The use of computer based models to assist communication has now become a standard practice in many design firms. Projects that provide prototypes and models for the users to evaluate early in the project development process experience lower levels of rework.

3.4.2.2.1.3. <u>Agile Method</u>

The agile method can be viewed as both a modern reinterpretation of design charettes or as a type of spiral development strategy. Small (eight person maximum) design teams are formed to work directly with the client or stakeholders to iteratively search out requirements and accompanying design solutions for a particular segment of the project. The length of each iteration varies somewhat with the specific form of the agile method being used (there are three popular forms; "scrum," the Rational Unified Process (RUP), and Extreme Programming) and may extend from a few days to six weeks. Planning is kept at a course-grain level and generally extends only two iterations into the future. Each iteration is expected to produce a testable end product that adds value regardless of whether additional iterations are, or are not, performed.

3.4.2.2.1.4. Broader Based Integrated Project Teams

The feasibility of atypical facility and equipment requirements should be verified by those that actually have to perform the construction or supply the equipment. This can be accomplished, in simple cases, through market surveys. On more complicated projects construction and component expertise should be added to the IPT. Consequence and Scenario Based Planning

3.4.2.2.1.5. Consequence and Scenario Based Planning

Many adjunct goals focus on the prevention of an undesired negative event or consequence. There are typically many different scenarios or pathways that can lead to these events or consequences. Each needs to be understood and then blocked though the development of specific requirements.

3.4.2.2.1.6. Sensitivity Analysis

Construction, procurement, and life cycle costs may be relatively insensitive to changes in a particular requirement or may undergo a linear, a non-linear, or a step function increase or decrease. The impact of changes should be evaluated and factored into the requirements definition process.

3.4.2.2.2. Strategies to Temporarily Compensate for Other Short Term Uncertainties

Schedule pressures such as consent degrees or time sensitive missions may necessitate that design and, in some unique cases construction, begin prior to the fully resolving the requirements and constraints. The strategies and procedures that should be utilized when this occurs are outlined next.

3.4.2.2.2.1. Set-Based Design

Set-based concurrent design postpones the need for commitment by using a set or range of requirements when beginning the design effort, rather than a single point requirement. The range or set of requirements is narrowed incrementally, with accompanying adjustments in the design effort, as uncertainties are eliminated and the requirements become firmer. Carrying multiple alternatives increases front-end costs, but also increases the project's ability to meet the imposed schedule.

3.4.2.2.2.2. Design Margins

Design margins are utilized during project development to temporary compensate for recognized uncertainties and unresolved differences of professional opinion regarding the correct method of calculation or analytical tools. Design margins differ from factors of safety in that:

- they are temporary and can be eliminated or reduced once the missing information is obtained or the differences of professional opinion are resolved and

- should be based upon **worst case**, rather than expected, outcomes.

The Secretary endorsed the importance of design margins in a March 2003 letter to the Defense Nuclear Facilities Safety Board stating that such margins should be carefully managed as a function of design uncertainty. The FPD and the IPT should ensure that formal design margins are established for each structure, system, or component and that these margins are appropriate to the situation.

3.4.2.2.2.3. Fallback Alternatives

Fallback alternatives should be identified and held in ready reserve whenever:

- a proposed design solution or component has a Technology Readiness Ranking of seven or below at this point in the project or

- market uncertainties exist that could result in a lack of competition or unavailability.

3.4.2.2.2.4. Strategies to Compensate for Longer Term Uncertainties

Two different strategies should be considered when the project is faced with longer term uncertainties.

3.4.2.2.2.4.1. Robust Design

Robustness is defined as the ability to endure unexpectedly adverse environments. As used in this case, it is an irreversible decision to proceed with construction on items such as building foundations or long lead procurements using the worst case situation as a design basis rather than delaying the project while differences in professional opinion or uncertainties are resolved. It is, in that regard, a permanent rather than a temporary strategy.

3.4.2.2.2.4.2. Real Options

The concept of a real option originated in the financial world and is defined as a right or ability, but not the obligation, to pursue a particular future course of action. Real options can generally be obtained only by an expenditure of funds. An example of a real option can be seen in a decision to buy right of way space for adding lanes when building a new highway. The additional lanes may never be constructed, but the option is available.

3.4.2.2.3. Strategies for Responding to Cost and Schedule Constraints

3.4.2.2.3.1. Reuse

The most successful sublevel strategy for meeting cost and schedule constraints is the use of existing designs or components that are readily available and have been proven in actual applications. Both the OMB and the U.S. Government Accountability Office

(GAO) endorse this strategy as a method of reducing risk and cost. IPT members should interview those currently using the design or components to verify their level of satisfaction and to gain the benefits of any lessons learned.

3.4.2.2.3.2. Modularity

Modular structures, systems and components are similar in concept to reuse and offer many of the same advantages. They can reduce both time and cost while concurrently reducing risk since the initial modules can be utilized for both verification testing and learning.

3.4.2.2.3.3. Design-Build Contracts

Design-Build contracts can reduce both cost and schedule. They are, however, applicable to only a narrow range of circumstances as is outline in paragraph 5g(3) of DOE O 413.3A. Design-build is not synonymous with fast tracking which initiates construction while design is still in progress.

3.4.2.2.3.4. Concurrent Engineering

Concurrent engineering (a.k.a. simultaneous engineering and early construction involvement) provides many of the cost and schedule advantages of design-build and applicable to a broader range of range of circumstances. It is widely used by in the commercial sector and can be accomplished by simply adding manufacturing or construction expertise to the design IPT. It provides a method for the designers to obtain the real world knowledge that is needed to avoid design solutions that appear good on paper but present downstream quality, cost, or schedule problems for the constructors and fabricators. Concurrent engineering has been confused with fast tracking in some oversight reports.

3.4.2.2.3.5. "Lean"

The Lean approach to design, manufacturing, and management is based on the highly successful Toyota production system. The Air Force and Department of Defense have been working with a consortium of manufactures and universities since 1993 to apply Lean concepts to government projects and programs. While the consortium has achieved very positive results, Lean is still not fully understood or applied by the bulk of the project management, design and construction community.

3.4.2.2.4. Strategies for Responding to Complexity

Complexity cannot be eliminated as either a challenge or a threat but can be reduced somewhat using the techniques discussed below.

3.4.2.2.4.1. Physical Complexity Responses

Government projects are inherently more physically complex than most similar private sector projects in that they involve a greater variety of goals, larger numbers of participants, and more interfacing internal and external organizations. IPTs and status reports provide a partial, but incomplete response. FPD's on larger projects should have full time staff members to coordinate information flow between the different units and ensure that the participants are working in synchronization. FPDs should also avoid solutions, such as intentionally procuring materials or services from large numbers of different individual suppliers, or large scale outsourcing that add physical complexity and increase the management and procurement workload.

Separate integrating and construction management contractors have been used by both the Department and other federal and state agencies as a response to physical complexity with mixed results. Those considering using either approach should invest the time necessary to fully understand the lessons that have been learned from these previous undertakings, particularly the higher profile failures.

3.4.2.2.4.2. Combinatorial Complexity Responses

Numerous "soft skill" approaches to the challenge of aligning different organizations with different goals have been advocated by business and project management publications over the past decade. The most successful of these continue to be IPTs and a achieving a clear understanding of group and task interdependencies. A proven method of showing group and task interdependences and helping to bring them into alignment is discussed below.

3.4.2.2.4.3. Dynamic Complexity Responses

A Dependence Structure Matrix (DSM) is a square matrix listing each activity, in the sequence in which it will be performed, on both the identically labeled vertical and horizontal axes (See Figure 1). Information flows between the activities are indicated by placing an "X" at the point the two activities intersect, using the sequencing nomenclature shown in the example below. An "X" below the diagonal line indicates a forward flow of information and is colored green; while an "X" above the diagonal line indicates than information flows backward from an activity that occurs later in time before the earlier event can be declared complete, and is colored red. Backward flows of information are particularly undesirable if the two interfacing actives are widely separated in time and other activities take place in between based on the earlier information since a larger quantity of work should be reiterated.

The planning approach should be changed, when the Dependency Structure Matrix indicates a backwards flow of information. The two tasks should be brought as close together as possible in sequence and managed as an interdependent or coupled pair if it is not possible to reverse their sequence. This type of situation appears on the Dependence Structure Matrix as a set of "X" at point of intersection both immediately below and above the diagonal line.

The quantity of information presented in the DSM can be increased by replacing the "X" with numbers that represent the quantity of information that flows between the linked activities or the level of interdependency. DSMs can also be developed using organizations, components, or project parameters as the two axis rather than activities.

The flow diagram corresponding to the example shown in Figure 1 is shown in Figure 2,

	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8
Activity 1								
Activity 2	✓							✓
Activity 3		✓						
Activity 4		✓					✓	
Activity 5			✓	✓		✓		
Activity 6			✓	✓	✓			
Activity 7								
Activity 8								

Figure 1 - Sample Dependency Structure Matrix

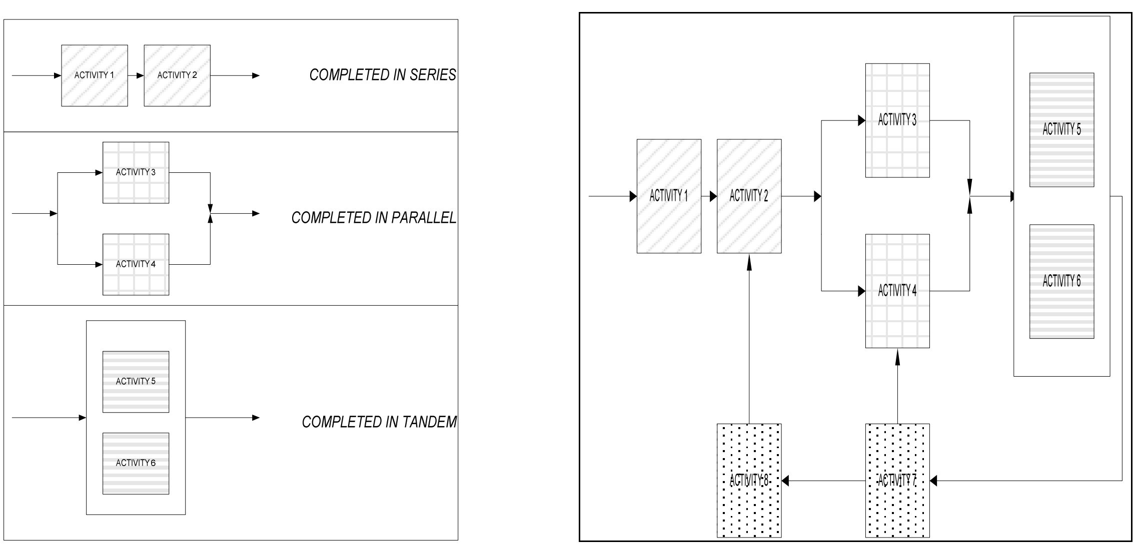

Figure 2 - Corresponding Flow Diagrams for the Figure 1 DSM

3.4.2.2.4.4. <u>Evaluative Complexity Responses</u>

A number of methods of responding to evaluative complexity are discussed in section 4.

3.5. Identify and Compare Alternative Design Concepts

DOE O 413.3A requires that alternative concepts be evaluated as part of the Project Definition Phase using Systems Engineering and other techniques and tools such as alternatives analysis and Value Engineering/Management.[25] Historically the process has confronted at least six major challenges.

- The identification, development, evaluation, and selection of alternate design concepts is often influenced more by the values of the organization performing the study and the types of design solutions that they are the most familiar with, than it is by the Department's and the stakeholder's requirements.
- Different stakeholders are likely to assign the requirements and constraints significantly different priority rankings, preventing the creation of a requirements priority list that is acceptable to all parties.
- Finding a collection of design solutions that provides the optimal answer for each individual requirement on a complex project will not produce a design solution that is optimal from a total project standpoint.
- Even the brightest of designers only has the cognitive capability to mentally integrate a small number (generally less than nine) of the requirements when pursuing a solution.
- The initial set of requirements is unlikely to accurately reflect the stakeholder's real needs or be fully achievable when matched against the constraints.
- Few people know how to handle the uncertainties that have been identified, and therefore circumvent the problem by making unwarranted assumptions such as the site's mission will not change in the future, soil explorations will not reveal any surprises, or there will be an adequate number of bidders/suppliers to provide full and open competition.

Most designers will pick one requirement around which the design will be optimized. They will then check to see if the resulting design solution appears to satisfy the other requirements. The following approach acknowledges this need to start with a single requirement, but provides a far more rigorous approach to ensure that all critical requirements are given equal consideration and that the six challenges listed above are met.

3.5.1. Identify the Dominant Requirements and Constraints

A small group (four or less) of dominant requirements and constraints should emerge from the above tasks and the program's, the FPD's and the IPT's experience on similar projects.

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[25] Value Management and this particular aspect of Systems Engineering are essentially synonymous in that both analyze the various elements of the project for the purpose of achieving the best value for the government. Value Engineering's objective is slightly different in that it has historically focused solely on achieving lowest cost. See DOE P 413.2, *Value Engineering*, and Public Law 104-106 Section 36 for additional information on Value Engineering.

This dominant group will automatically include safety if the project is a Hazards Category 1, 2, or 3 nuclear facility and is likely to include cost and staffing constraints. The requirements or constraints identified in this group should be used as the conceptual alternatives to be evaluated using a design for "X" approach.

3.5.2. Design for "X"

The design for "X" approach can be seen as an elaborate design charette where different solutions are quickly developed and presented to better determine priorities and trade-offs. It is ideally suited for evaluating conceptual alternatives in that it can be utilized when neither the relative priority of the dominant requirements nor their degree of interdependency can be readily determined. Different teams pursue independent design solutions in parallel, each starting with a different dominant requirement or constraint and developing a high level design solution that they believe optimizes the assigned requirement or constraint and satisfies the other requirements and constraints.

The depth to which a design for "X" study should be taken is project dependent and cannot be pre-prescribed. Normally, no more than a month should be needed on even the most complex of projects to achieve enough insight to:

- Select the design solution(s) to be used as a basis for full conceptual development, Critical Decision 1 approval, and Preliminary Design. (The selection may be one developed by a single team or a composite of those proposed by different teams.)
- Understand the tradeoffs that can, and cannot be made.
- Identify those requirements and constraints that are open to misinterpretation and need to be written to a deeper depth before preliminary design is initiated.
- Determine if the solutions are able to accommodate the uncertainties.

3.5.3. Check the Resulting Design Solutions

The design solutions proposed by each design for "X" team should be checked internally by the FPD and the IPT before deciding which design solution to propose for advancement. This check is a separate forerunner to the three independent Critical Decision 1 reviews specified in DOE O 413.3A in that it focuses nearly totally on requirements, constraints, and uncertainties.

3.5.4. Verify that the Design Solution Satisfy the Requirements

Each design for "X" team should provide evidence that their design solution adequately addresses each requirement. The degree of evidence that should be provided depends upon the importance of the requirement or constraint and the novelty of the design solution. Data showing that the proposed solution has satisfied similar requirements on past projects is desirable.

3.5.5. Look for Misaligned Linkages

Many requirements and constraints should be either positively or negatively linked from a design solution standpoint. A design solution that satisfies a demanding schedule requirement should, for example, also satisfy technical readiness requirements since proven technologies and approaches can normally be designed, procured, and constructed faster than first-of-a-kind technologies and approaches. A design solution that runs counter to normally expected linkages indicates a risk that needs to be fully evaluated prior to further pursuit. Such misalignment frequently involves schedule or cost goals that are incompatible with other objectives.

3.6. Incorporate Pre-conceptual Findings and Conclusions in the Project and Contract Documents

The information developed and the conclusions reached in sections 3.1 through 3.5 should be utilized as a "stepping off point" for the following documents which are begun next:

- Risk Management Plan
- Acquisition Strategy
- Project Execution Plan
- Architect-Engineers Statement of Work
- Architect-Engineer Services Selection Criteria
- Government Cost Estimate for Architect-Engineer Services
- Technology Maturation Plan
- Federal and M&O Contractor Staffing Plan
- Design Verification Roles and Responsibilities including a "Design Authority" Recommendation

The first three of these documents are covered in separate Guides and do not need to be addressed here. The latter six documents are not covered elsewhere and are addressed next.

3.6.1. Architect-Engineers Services Statement of Work

The process for acquiring architect-engineering services is prescribed in Subpart 36.6 of the Federal Acquisition Regulations. A contracting officer (CO) will be named to manage the acquisition process and to be the selection authority. The FPD and the IPT should provide the CO with a Statement of Work (SOW) that should:

- specify the Department's expected outcomes from the conceptual design, including the specific problems that should be solved;

- detail the tasks that the Architect-Engineer will perform;
- identify the associated tasks (such as determination of the site's geological conditions and local market limitations) that the Department or the M&O will perform;
- identify any specific tools and techniques that the Architect-Engineer should utilize;
- outline the information that the Department and/or the M&O will supply to the Architect-Engineer and when that information will be available;
- identify the performance standards for the conceptual effort, including quality, quantity, delivery schedules, packaging, etc.; and
- identify any design trade-off decisions that the Department wishes to retain as its authority. The latter should include the degree of design conservatism (i.e., design margins) to be maintained to offset the uncertainties and unknowns that are present at the early stages of the project.

The SOW, a critical document if the Department's "Waterfall" development strategy, is being used since it will become the sole official source of design direction to architect-engineer for the term of the contract. Post award changes to the SOW will have to be processed through the CO and be accompanied with a Government estimate of the cost impact as described in section 3.6.3. The creation of a SOW that adequately foresees all of the tasks that the architect-engineer will need to perform and identifies all of the design trade-off decisions that the Department wishes to retain control over can be highly challenging, if not impossible, on complex longer duration projects. There is also a significant timing problem on Hazard Category 1, 2, and 3 nuclear projects since the information in the Conceptual Design Safety Report, which is being developed concurrently, is needed in order to create the SOW.

The best approach in such cases may be one of the Evolutional Development Strategies discussed in section 3.4.2.1.2. The basic concept behind Incremental Development strategies can, for example, by simply providing a broader description of the Architect-Engineers total collection of tasks and then issuing more detailed tasking orders prior to the initiation of each project phase. This will result in some interruptions of the design effort, but will provide the FPD and the IPT with an increased ability to steer the Architect-Engineers activities.

The development of an adequate description of even the first two increments of the Architect-Engineers contract (conceptual and preliminary design) presents a significant challenge given the number of activities that are being conducted simultaneously during both increments and the high degree of interdependence between these activities.

DOE O 413.3A does not define either the specific content or the expected level of definition of either increment. It is up to the FPD and the IPT to make this determination based on the type of project being undertaken and the specific needs of the other project participants. For the conceptual design increment these needs are certain to include at least the following types of drawings which will be needed by those developing the Preliminary Hazards Analysis; the preliminary Security Vulnerability Assessment the Safety Design Strategy, Conceptual Safety

Design Report, and the Risk and Opportunities Assessments for Hazard Category 1, 2, and 3 nuclear facilities, the environmental impact documents; the project cost range; etc.

- Facility site location and utility connections
- Floor plans, elevations, and cross sections showing dimensions and the location of all major processing and building equipment.
- The structures, systems, and components selected to meet the requirements
- Building materials
- Structural loads, spans, and design approaches
- Process block flow diagrams
- Preliminary one-line diagrams for the:
    - Heating, ventilating, air conditioning systems
    - Electrical power system
    - Mechanical services systems
    - Instrumentation and control systems
- Process diagrams and configurations including the sizing of all major process systems and components

3.6.2. Architect-Engineer Services Selection Criteria

Architect-engineering service contracts for Government projects are awarded based demonstrated competence and qualifications. The FPD and the IPT should, accordingly, specify the capabilities and technical competence being sought in adequate detail to allow the CO and the evaluation board to ensure the candidates process the required knowledge, skills and abilities and to differentiate between the various candidates. This can be accomplished by cross linking capabilities and technical competence expectations to the firm's actual performance on similar Government and private sector projects. Quantitative measures such as the number and type of Request for Information, Engineering Change Notifications, Design Change Notifications, and Non-Conformance Reports provide valuable information on both the quality of the Architect-Engineer Firm's work and their understanding of the construction and manufacturing constraints that they should take into consideration when developing their design solutions.

If it is properly executed, the Selection Criteria can also serve as a vehicle for fulfilling the DOE P 450.4, *Safety Management System*, and DOE O 413.3A joint requirement that personnel possess the experience, knowledge, skills, and abilities necessary to discharge their responsibilities.

3.6.3. Government Cost Estimate for the Architect-Engineer Services

Subpart 36.605 of the Federal Acquisition Regulations specify that "an independent Government estimate of the cost of architect-engineer services shall be prepared and furnished to the contracting officer before commencing negotiations for each proposed contract or contract modification expected to exceed the simplified acquisition threshold" and that this "estimate shall be prepared on the basis of a detailed analysis of the required work as though the Government were submitting a proposal." The degree of accuracy that can be achieved in preparing such estimates depends on both the clarity of the SOW and the length of the contract.

3.6.4. Technology Maturation Plans

Technology Maturation Plans (TMP) detail the steps necessary for developing the technologies and/or design solutions that are currently less mature than desired, to a level that they can be safety inserted into the project. The TMP should identify:

- the specific tasks to be undertaken;
- the results to be achieved for a claimed advancement to a higher TRL to be statically valid
- the TRL expected to be reached at each of the Critical Decision points;
- the organization that will perform the maturation activities;
- the cost of these activities; and
- the off ramp that will be taken if results are less than required at each Critical Decision.

3.6.5. Federal and M&O Staffing Plan

The Acquisition Executive should have a detailed understanding of the Department's and the M&O contractor's staffing needs when making Critical Decision 1. This understanding can be provided through the submission of an updated IPT Charter and an accompanying project staffing plan that can be approved in conjunction with Critical Decision 1. The Staffing Plan should cover tasks such as preparation of a Preliminary Safety Validation Report and the Performance Baseline Validation Reviews that are performed by non-project personnel so that the Acquisition Executive, the site office manager, and other supporting organizations can foresee, and properly plan for the staffing loads they will have to accommodate.

3.6.6. Design Verification Roles and Responsibilities

The Department's directives contain multiple requirements and recommendations pertaining to project reviews, two of which are specifically aimed at ensuring that the design outputs satisfy project requirements. They are:

- "Beginning at CD-1 and continuing through the life of the project, as appropriate, Design Reviews are performed by individuals external to the project …to determine if a product (drawings, analysis, or specifications) is correct and will perform its intended functions and meet requirements. Design Reviews must be conducted for all projects and must involve a formalized, structured approach to ensure the reviews are comprehensive, objective, and documented."[26]

- "Design verification is a documented process for ensuring that the design and the resulting items will comply with the project requirements." "Design verification should be performed by technically knowledgeable persons separate from those who performed the design."[27]

Other DOE O 413.3A requirements that touch on the subject without specifically indicating that reviews should verify that the design satisfies the requirements are:

- The IPT "reviews and comments on project deliverables (e.g., drawings, specifications, procurement, and construction packages)."[28]

- "Contractors performing design for project must at a minimum conduct a Preliminary and Final Design Review, in accordance with the Project Execution Plan. For nuclear projects, the design review will include a focus on safety and security systems."[29]

DOE O 413.3A also specifies that the Acquisition Executive designates the Design Authority for the project at Critical Decision 1. The Design Authority (aka the Engineering Technical Authority) is the individual who formally signs off on the design drawings, calculations, and specifications. The Design Authority is typically not a DOE employee or official. This role and responsibility for assuring the technical adequacy of the design is normally delegated to the M&O contractor.

DOE-STD 1073, *Configuration Management*, provides the following additional information on the roles and responsibilities of the Design Authority on Hazard Category 1, 2, and 3 and nuclear facilities.

- "Contractors should establish the design authority for each SSC (structure, systems, and components). [30]

- The above "responsibilities are applicable whether the process is conducted fully in-house, partially contracted to outside organizations, or fully contracted to outside organizations." [31]

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[26] DOE O 413.3A, paragraph 5h(2)(c), page 22.
[27] DOE G 414.1-2A, section 4.6.5
[28] Paragraph 6m(9), page 42
[29] Attachment 2, Item 13
[30] Paragraph 3.5, page 3-9
[31] Appendix B, page B-3

- The design authority should define the category (mission critical, environmental protection, costly, critical software, master equipment list, adjacent) that the SSCs fall under.[32]

- "The contractor must assign a database owner for the equipment database, with established roles and responsibilities … the design authority is a likely choice. As such, the design authority would be the focal point for resolving discrepancies and updating the database."[33]

- "When facilities or systems are turned over from one organization to another, the design authority may also change. This may occur over a period of time. Procedures should be developed to govern this turnover. However, at any given time, there should be a single, defined authority for each SSC." [34]

- "Changes that affect the design basis require a design analysis by the design authority."[35]

- "The design authority should prepare a change control package consistent with the design process and controls for the proposed change."

- "The design authority must approve partially implemented changes prior to operation." [36]

The FPD and the IPT should provide the Acquisition Executive with a project design Roles and Responsibilities Proposal, which should include both the Department's and the M&O contractor's specific validation responsibilities including those assigned to the Design Authority. The depth and frequency of validation should be risk based with priority placed on the validation of high risk and importance requirement. It is recommended that these high priority requirements be checked at each formal review point.

It will be extremely difficult for those performing design verification roles to determine how, or if, preliminary designs that the architect/engineering firms develop and submit satisfy the Department's requirements unless an accompanying "roadmap" is also provided. The FPD should ensure that the need for such a "roadmap" is specifically identified in the SOW together with the methodology to be used in creating this "roadmap."

System Design Descriptions have proven to be highly effective in communicating or "mapping" the linkage between the design solutions and the Department's requirements on even the largest and most complex of projects and should be used as the benchmark against which other possible methods are evaluated. Information on System Design Descriptions can be found in DOE Standard 3024-98, *Content of System Design Descriptions* and Section 3.7 of DOE-STD-Standard 1073, *Configuration Management.*

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[32] Paragraph 3.2, page 3-5
[33] Paragraph 3.8, page 3-13
[34] Paragraph 3.5, page 3-9.
[35] Paragraph 5.3.1.1, page 5-8
[36] Paragraph 5.2.2, page 5-5

4.0 SUPPORT CRITICAL DECISION 1

DOE O 413.3A requires that the IPT review all Critical Decision packages and recommend whether they should be approved or disapproved.[37] Fulfillment of this recommendation involves far more than just checking the conceptual design report. It should also be based on: 1) whether the Critical Decision requirements specified in Table 2 of DOE O 413.3A have been properly completed; and, 2) a self evaluation of whether an adequate level of planning and risk mitigation/avoidance has been undertaken for the upcoming phase of the project. Each is addressed below for the Critical Decision 1.

4.1. DOE O 413.3A Critical Decision 1 Requirements

Most of the actions specified in Table 2 of the Order are performed by or involve different DOE, M&O contractor organizational elements. These include:

- Development of the Conceptual Design Report.
- Development of the Acquisition Strategy.
- Preparation of the Preliminary Project Execution Plan.
- Preparation of the Project Data Sheet.
- Preparation of a Preliminary Security Vulnerability Assessment Report.
- Preparation of a Preliminary Hazard Analysis Report for facilities that are below Hazard Category 3 threshold as defined in 10 CFR 830, Subpart B.
- DOE field level approval of the Preliminary Hazard Analysis Report.
- Preparation of a Safety Design Strategy, Preliminary Hazard Analysis, Risk and Opportunities Assessment, and Conceptual Safety Design Report for Hazard Category 1, 2, and 3 nuclear facilities.
- Preparation of a Preliminary Safety Validation Report based on DOE's review of the Conceptual Safety Design Report.
- Compliance with the One-for-One Replacement legislation mandated in House Report 109-86.
- Determination that the (site's already existing) Quality Assurance Program is acceptable, continues to apply, and fully addresses all of the applicable Quality Assurance Criteria defined in 10 CFR 830 Subpart A and DOE O 414.1C.

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[37] Paragraph 6m, page 42.

- The Technical Independent Project Review that is required for high-risk, high-hazard, and Hazard Category 1, 2, and 3 nuclear projects.
- Preparation of the environmental documents.
- Preparation and processing of the Project Engineering and Design budget request.

Further, each action commences at a different point in time and most are dependent upon the receipt of information from one or more of the other organizations. The project is responsible for keeping each organizational element and activity in synchronization with the others. This can be a full time job for multiple individuals on even relatively modest projects since the individual actions are historically highly dynamic in nature and each change or perturbation tends to impact the other organizational elements. Such interdependencies between the different activities are often difficult to foresee. Negative findings and recommendations from the Technical Independent Project Review may, for example, result in the need to undertake previously unplanned work that in turn pushes the total cost of the conceptual effort over the $3 million conceptual design notification threshold imposed by Title 50 United States Code for projects authorized by the annual National Defense Authorization Act and necessitates a preparation and transmittal of a Congressional Notification.

4.2. Adequate Planning and Risk Reduction for the Next Project Phase

The adequacy of the project's advanced planning and risk reduction, activities such as those just discussed in section 4.1 for Critical Decision 1, is one of a number of the readiness-to-proceed questions that the IPT should ask themselves before appearing before the Acquisition Executive. Others include the quality of the cost and schedule estimates for the upcoming phase; the availability of funds for these activities; and, the status of the Architect-Engineer's contract and work force. The underlying issue is again the project's ability to keep all of these diverse activities in synchronization.

Larger projects have historically experienced high levels of rework with accompanying cost and schedule impacts because design and construction elements have been allowed to proceed in advance of full requirements definition and/or without adequate information on site conditions, operating environments, market capabilities, etc. The data base of actions being taken to eliminate uncertainties and knowledge gaps that was discussed in section 3.4.2.2 should be used together with the larger list of project development strategies provided in section 3.4.2 to prevent premature commitments of resources and help keep all of the project's activities in synchronization.

One of the more critical readiness-to-proceed questions that should be a resolved prior to advancing to Critical Decision 1 is what will constitute Preliminary Design completion? Order 413.3A does not define the level of calculation basis that should be achieved, which design elements should reach the component depth of detail, the accuracy to which equipment and structure components should be sized, the number or type of assumptions that are still allowable, etc. These questions are seen as project specific and left up to the FPD and the IPT to decide. They should be fully addressed in the SOW for preliminary design Architect-Engineering services and submitted to the Acquisition Executive for his or her approval.

4.3. Implement Requirements Change Control

The requirements that were captured as part of the pre-conceptual planning effort should be submitted to the Acquisition Executive for acceptance or rejection as part of Critical Decision 1. If approved, they should be placed under the non-Performance Baseline side of the project's formal change control system and utilized as the criteria for verifying/validating the acceptability of all future design solutions.[38]

5.0 TRANSITION TO AN OVERSIGHT AND COORDINATION ROLE UPON CRITICAL DECISION 1

DOE O 413.3A is based on the concept that the FPD and the IPT will transition to predominately an oversight and coordination role upon approval of Critical Decision 1. These two intertwined roles are discussed below.

5.1. Integrate the Preliminary Design Activities

The preliminary design activities specified in DOE O 413.3A and Standard DOE-STD 1189 are normally performed by more than twenty separate organizational elements. Each organizational element requires input from other organizations and, in turn, provides output information that the other organizations require. Interactions between the various organizational elements need to be highly iterative and should be planned and implemented using the strategies and tools specified in section 3.4.2 of this Guide.

This planning and integration should be performed by the FPD and the IPT since a number of the organizations involved are at the Headquarters level of the DOE organization.

5.2. Project Oversight

The extent of this transition to an oversight role and the length of time over which it takes place should be risk based. Noncomplex projects with fully defined requirements and few uncertainties require only a minimum transition period and relatively sparse interactions between the Architect-Engineer's designers and the other project participants. Conversely, the transition should occur at a slow pace with high levels of interactions maintained for the duration of preliminary design on:

- Complex projects
- Projects on which the requirements are still evolving.
- Projects where there are still significant uncertainties.
- Hazard Category 1, 2, and 3 nuclear projects.
- Projects of greater than normal management and/or public interest.

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[38] See DOE O 413.3A, paragraph 5.i.(3), page 24 for the two categories of change control.

Those situations that require high levels of interaction with the Architect-Engineer should be handled with care to ensure that individual level discussions are not interpreted as contractual direction by the Architect-Engineer's staff and that all project participants fully understand that contractual direction only come through the CO. Similarly, these interactions need to be structured in such a way that they do not violate the Order 413.3A's requirement that the Federal Project Director "serve as the single point of contact between Federal and contractor staff for all matters relating to a project and its performance."[39] These constraints have been successfully handled on past projects by: 1) having the FPD serve as the Contracting Officer's Representative[40]; 2) holding regularly scheduled meetings between the Architect-Engineer's design team and the FPD/IPT; and, 3) inserting an on-site IPT field representative or representatives (working under a tightly written delegation of authority memorandum) in the Architect-Engineer's offices. The drafting of "Agreement and Commitment" memos (that only become effective upon the CO's signature) at the end of each periodic meeting has also proven to be a useful method of achieving the level of interactions necessary to prevent undesirable schedule delays and design breakage without violating contractual protocol.

The degree of interaction between the FPD/IPT, the M&O, and the Architect-Engineer Services Contractor should, under either case, be adequate to satisfy DOE O 413.3A requirements that:

- The FPD "evaluates and verifies reported progress; makes projections of progress and identifies trends."[41]

- The FPD "is responsible for (the) timely, reliable, and accurate integration of the contractor performance data into the project's scheduling, accounting and performance measuring systems."[42]

- The IPT "perform periodic reviews and assessments of project performance and status against established performance parameters, baselines, milestones and deliverables."[43]

- The head of the field organization, and the Acquisition Executive: "Develop project performance measures, and monitor and evaluate project performance throughout the project's life cycle."[44]

- The Acquisition Executive conduct monthly and quarterly project performance reviews.[45] plus, DOE O 414.1C's (*Quality Assurance*), requirements that:

    - Services that do not meet established requirements be identified and controlled.[46]

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[39] Paragraph 6g(8), page 39.
[40] Paragraph 6g(9), page 39.
[41] Paragraph 6g(7), page 39.
[42] Paragraph 6g(6), page 39.
[43] Paragraph 6m(6), page 42.
[44] Paragraph 6e(7), page 37.
[45] Paragraph 6f(7), page 38.
[46] Paragraph 4b(3)(b), page 4.

- Design interfaces be identified and controlled.[47]

5.2.1. Select Preliminary Design Performance Metrics

Earned value performance metrics are not formally required until Critical Decision 2 and DOE O 413.3A does not specify how preliminary design progress should be measured; therefore, the FPD will be forced to determine, in conjunction with the Acquisition Executive, an appropriate set of project specific performance metrics for this period of the project. This set of metrics should be weighted towards ensuring that the following mutually dependent sub-elements of the preliminary design phase are in synchronization.

5.2.1.1. Architect-Engineering Services

The Architect-Engineering Services tasks and products of greatest risk and importance should be tracked from the perspective of: 1) the Architect-Engineers schedule of deliverables as stated in the SOW; and, 2) the informational needs of the other tasks that must also be completed prior to Critical Decision 2. These tasks are addressed below.

5.2.1.2. Baseline Development and Review

The performance baseline development process, which is described in a separate DOE O 413.3A Guide, should be tracked with an eye towards the follow-on Performance Baseline Validation Review that DOE O 413.3A requires be completed before Critical Decision 2.

5.2.1.3. NEPA Documentation

The status of National Environmental Policy Act Compliance documentation, public meetings, and decisions should be tracked with emphases on its alignment or misalignment with the Architect-Engineering's activities and the overall preliminary design schedule.

5.2.1.4. DOE Standard 1189

If the project is a Hazard Category 1, 2, or 3 nuclear facility, progress on the following activities that are required by Standard 1189 should be tracked:

- Demonstration of how the preliminary design will satisfy the nuclear safety design criteria in DOE O 420.1B.
- Updating of the Safety-in-Design Risk and Opportunity Assessment.
- Development of the Preliminary Safety Design Report.
- Development of the systems or process level hazard analysis.
- Updating of the Fire Hazards Analysis.

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[47] Paragraph 4b(6)(c), page 5.

5.2.1.5. Independent Cost Estimate

DOE O 413.3A requires that either an Independent Cost Estimate or an Independent Cost Review be conducted prior to Critical Decision 2. The preparation for and performance of these activities should be tracked since an Independent Cost Review may be on the critical path and an Independent Cost Estimate is certain to be on the critical path.

5.2.1.6. Design Rework

The cost and time for design rework should be tracked against original allowances. Complex projects have historically been marked by high level rework or iteration that is not accounted for in either the cost estimates or schedules. Design approaches, drawings, specifications, reports, and documents are repeatedly abandoned or modified because of unidentified requirements, changes, incompatibilities with other areas of the project, and feedback from reviews. A significant amount of the cost and schedule growth that has occurred on the design portion of the Department's projects can be traced back to such iteration.

5.2.1.7. Elimination of Uncertainties/Unknowns

A formal data base that identifies each uncertainty, unknown, and unverified assumption was created as part of the pre-conceptual engineering project activities as described in section 3.4.1.2.2. The elimination of these uncertainties, unknowns, and unverified assumptions should now be tracked, together with the any needed increases in TRL, as part of the oversight process. The tracking process should again focus on ensuring that the information that is required by dependent sub-elements of the project is available on time.

5.2.2. Integrate Quality Assurance and Project Management Oversight

The degree of commonality between quality assurance and systems engineering is repeatedly mentioned throughout this Guide. The FPD and the IPT, should take advantage of this commonality by integrating oversight activities at the start of preliminary design. This should provide improved oversight and concurrently reduce the amount of time the architect-engineer and the other project participants expend providing information to the oversight functions.

5.2.3. Determine the Timing and Depth of Periodic IPT Reviews

It is possible, on shorter duration projects, for the FPD and the IPT to rely on the Performance Baseline Validation Independent Review and the project initiated Design Reviews to surface design errors. This approach is not workable on longer duration projects since preliminary design can take well over a year to complete and the cost and schedule impacts of waiting until the preliminary design work is finished to identify errors could be severe. It is more cost effective on such projects for the IPT to conduct mid point reviews that are timed to:

- the Architect-Engineer's internal design decision points,
- the possible cost and schedule impacts of design rework, and
- the importance of the design element.

5.2.4. Intercede While Emerging Problems Are Still Correctable

Oversight involves taking corrective actions as well as observing. The FPD and the IPT should, for example, direct the Architect-Engineer to increase the design margins on a particular structure, system, or component if they determine that such increases are needed to ensure that that the proposed design solutions adequately compensate for still unresolved uncertainties and unknowns or newly recognized uncertainties and unknowns. It is important, from a cost and schedule impact standpoint that such direction be given as soon as the FPD and the IPT become aware of the problem since delays can result in additional rework and design breakage.

Most directions for corrective actions will need to be transmitted to the CO or the Acquisition Executive for implementation since the majority of the Preliminary Design phase tasks are performed by organizational elements that are outside of the FPD's direct line of authority. The transmittals should be linked with the mandatory monthly and quarterly project performance reviews when time allows since these reviews provide a natural setting for in depth discussions of the problem and the need for action. Issue and risk identification and correction should be a standard element of these reviews. Two of the most frequently overlooked, but important project metrics are: 1) how quickly problems and negative risks trends are identified; and, 2) how quickly these same problems and negative risk trends are then corrected.

6.0 OVERSEE AND COORDINATE THE FINAL DESIGN ACTIVITIES

The magnitude of the FPD's and the IPT's coordination activities declines significantly during the final design phase of the project as can be seen from the reduced number of prerequisite tasks listed in Table 2 of DOE O 413.3A. The different organizational elements should now be in a position to work relatively independently of each others. This, together with the approval of the project performance baselines at Critical Decision 2, changes the thrust of the FPD's and the IPT's oversight and reporting effort to earned value variance identification and analysis. Risk management should, however, continue to be a major focus since earned value metrics may not pick up emerging market situations and other changes in the external environment.

Reductions in the FPD's and the IPT's coordination work load will be partially offset by increase in three other areas:

- change control,
- product acceptance/verification, and
- construction and procurement support.

6.1. Control Baseline and Requirements Changes

The Project Performance Baselines approved at Critical Decision 2 are placed under the formal control system described in the Project Execution Plan and DOE O 413.3A.[48] The FPD and the IPT should develop and implement a supplemental set of project level controls that operate below the thresholds specified in DOE O 413.3A and serve as early warning indicators of negative trends that necessitate corrective action.

Any additional requirements emerging during this phase of the project should be processed individually by the FPD and the IPT and immediately submitted to the Acquisition Executive for approval together with an analysis of the new requirement's impact and a recommendation as to how it should be back fitted into the on-going project.

6.2. Product Acceptance/Verification

The product acceptance/verification tasks assigned to the FPD and the IPT in the Proposal that was submitted to the Acquisition Executive prior to Critical Decision 1 (see paragraph 3.6.6 of this Guide) should be performed incrementally as the design products are completed to avoid the workload spike that would occur if they were treated in mass at the end of Final Design. Such incremental verifications should not introduce additional risk if the project tasks are properly synchronized.

6.3. Provide Construction and Procurement Support

As was the case with design, the CO rather than the FPD is responsible for the selection and award of the construction contract(s) and any Government furnished equipment. The CO may elect to self perform these efforts or may formally devolve them to the M&O contractor. Both the governing rules and the supporting activities performed by the FPD and the IPT remain the same regardless.

6.3.1. Provide Information to Help the CO Determine the Appropriate Form of Contract

The type of contractual relationship selected for equipment and construction is dependent upon:

- the level of risk and uncertainty inherent in the work to be performed and
- market conditions.

6.3.1.1. Integrate Risk Considerations into the Contract Form Selection Process

The Department's Acquisition Guide specifies that the contract type should be commensurate to the level of risk reflected in the Statement of Work. If too much risk is assigned to the contractor few, if any, bids or proposals may be received and those that are received will typically include significant additional allowances to cover the contractor's risk.

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[48] Paragraph 5i, pages 23 and 24.

Some of the risk factors that the DOE or the M&O contracting officer will take into consideration when selecting the form of contract to be utilized are:

- The type and complexity of the requirements. Requirements that are complex or unique to the Government increase the level of risks and suggest the use of cost reimbursement type contracts that shift the risk from the contractor to the Department.
- The urgency of the requirement results in the Department assuming a greater proportion of the risk or offer incentives to ensure timely contract performance if there is schedule urgency.
- The longer the performance period of the contract, the greater the possibility for unforeseen events.
- Contractors will be reluctant to shoulder the cost risk associated with technical challenges that they have not previously faced.
- Small firms may not have the financial means to take on risks.

The FPD and the IPT need to provide the contracting officer with the information necessary to make the above determinations and understand the interdependencies between quality and quantity of information that they can provide, the type of contract selected, and the ensuing relationship between the Department and the contractor. The types of contracts most frequently utilized for construction and government furnished equipment are discussed below together with the circumstances under which each is appropriate.

6.3.1.1.1. Firm-Fixed Price Contracts

Firm-fixed price contracts are generally utilized for construction. They require that the supplier deliver a defined product at a specified price at a specified time. Firm-fixed price contracts can accommodate uncertainties only if they can be fully identified and incorporated into the work scope at the time of award at a price that is acceptable to both parties. They place 100 percent of the responsibility and risk on the contractor. The Department's influence into how the product is developed is limited to the specific terms and conditions of the contract. Further information can be found in FAR Subpart 16.202.

6.3.1.1.2. Firm-Fixed Price Incentive Contracts

Firm-fixed price incentive contracts may be appropriate when there is uncertainty as to the cost of the product. They require agreement on: a possible range of cost; a reasonable target cost and target profit; a price ceiling; and, a share formula for establishing the final price. The share formula may be varied to fit the specific situation, commensurate with the degree of confidence both parties have in the range of possible cost and in the possible cost variations above or below target cost. The contractor is liable for all costs above the specified cost ceiling.

Firm-fixed price incentive contracts are not suited for situations involving technical uncertainty. Further information can be found in Subpart 16.403-1 of the FAR.

6.3.1.1.3. Cost-Plus Incentive Fee Contracts

Cost-plus incentive fee contracts are appropriate when performance objectives are known and there is high confidence that these objectives can be achieved; but there are technical and cost uncertainties. A target cost; a target fee; minimum and maximum fee limits; a fee adjustment formula; and, delivery, performance or cost incentives are negotiated at the time of contract award. Overall weight factors should be set for the different incentive factors.

Further information can be found in Subparts 16.304 and 16.405-1 of the FAR.

6.3.1.2. Cost-Plus Fixed Fee Contracts

Cost-plus fixed fee contracts are appropriate when there is high technical and cost uncertainty. There are two separate forms of cost-plus fixed fee contracts, a Completion Form and a Term Form. An identified product is specified under the "Completion Form" of a cost-plus fixed fee contracts, whereas the contractor is only obligated to deliver a specified number of hours for a specified time period under the Term Form of contract. The Completion Form is preferred over the Term Form.

Cost-plus fixed fee contracts provide minimum incentive for the contractor to control cost. Departmental oversight is the only assurance that efficient methods and effective cost controls are utilized. They normally should not be used once there is a high degree of probability that the product can be successfully developed and the Department has established reasonably firm performance objectives and schedules. Further information can be found in Subpart 16.306 of the FAR.

6.3.1.2.1. Cost-Plus Award Fee Contracts

Cost-plus award fee contracts are appropriate when the level of effort and the feasibility of the undertaking have been established; but milestones, targets, or goals to measure the contractor's performance cannot be expressed in objective terms. All allowable costs are reimbursed by the Department. The contractor's fee is established subjectively using an award fee evaluation criteria that include identified performance ranges. Cost-plus award fee contracts are not considered to be appropriate once requirements are defined.

Further information can be found in Section 16.305 and 16.405-2 of the FAR.

6.3.1.3. Integrate Market Conditions into the Contract Selection Process

Manufacturers and constructors are generally unwilling to invest the funds necessary to prepare a fixed price bid for a federal project if equivalent private sector work is available. This has led to a general lack of competition at many DOE sites with only one to two bids being submitted in response to many solicitations and those bids that are received being significantly higher than the government estimate. The FPD and the IPT should utilize the information they have obtained though their market surveys to identify those situations when the most cost effective solution would be to use one of the cost-plus forms of contracting. These situations will also generally be those that involve significant financial risk for the bidders.

6.3.1.4. Provide an Independent Government Estimate

Subpart 36.203 of the Federal Acquisition Regulations specify "an independent Government estimate of construction costs shall be prepared and furnished to the contracting officer at the earliest practicable time for each proposed contract and for each contract modification anticipated to exceed the simplified acquisition threshold." "The estimate shall be prepared in as much detail as though the Government were competing for award."

An independent estimate that is developed in strict accordance with this last sentence provides the FPD with both a basis for judging the reasonableness of the bids and an opportunity to discover previously unnoticed omissions, errors, and risk risers. The likelihood of such valuable discoveries taking place can be increased by using a truly independent estimator whose only source of information is the same bid package that the contractors and vendors will receive and requiring that he submit the same "Requests for Information" (RFI) when confronted with an unclear specification or drawing.

Some degree of iteration is an unavoidable part of combining different frames of reference and should be accepted. The FPD's and IPT's focus should, therefore, focus on controlling the cost and schedule impacts of iterations, rather than attempting to eliminate the iterations. This can be done using a simple Systems Engineering tool called Dependence Structure Matrix models that show the existence of dependencies between different activities in a format that is clearer and easier to read than flow diagrams and provides information that cannot be conveyed in most Critical Path Networks.

6.3.1.5. Determine if Construction and Procurement Should Be Split into Multiple Contracts

Construction and procurement can be combined into a single or multiple contracts. Single contracts place all coordination responsibilities on one contractor and are far easier for the Department or the M&O to administer. They can, however, also become so large on major projects that only a few companies have the resources necessary to either bid or successfully perform the work. Single large contracts can similarly require major step increases in project funding levels that can tax the Department's budgetary ceilings. Acquisition Executives and FPDs have, occasionally attempted to alleviate these problems by breaking construction into multiple packages and self procuring major equipment items. This approach transfers contractor and procurement integration responsibilities back to the M&O or the project and can quickly overwhelm these staffs.

As an alternative, a Construction Manager or Integrator can be utilized to place and manage these individual contracts. This can be done as either a contracted service or as a fixed price At Risk Construction Management Contract. Both approaches have significant advantages and disadvantages and should only be pursued after careful, project specific evaluations by the FPD and the IPT.

7.0 OVERSEE CONSTRUCTION

The FPD and IPT focus shifts to ensuring that the prime construction contractors, component manufactures, and subcontractors comply with the requirements of DOE O 413.3A and DOE O 414.1C, *Quality Assurance*, with Critical Decision 3 approval. Their activities now entail:

- assisting the CO evaluate and select bidders based on the bidders past performance on similar undertakings,
- ensuring that the requirements flow down to the subcontractors,
- establishing procedures to detect and prevent quality problems,
- reviewing and approving the contractors Quality Assurance Plan, and
- verifying and accepting end product.

In performing these duties the FPD and the IPT should track the following items and recommend corrective actions where appropriate:

7.1. Requests for Information

Requests for Information by the bidders are an indication that the bid packages (drawings or specifications) are incomplete, unclear, or conflicting. The FPD and the IPT should reassess the bid packages in light of requests for information and formally modify the drawings and specifications accordingly.

7.2. Engineering Change Notices (ECNs)

The FPD and IPT should maintain a log of all Engineering Change Notices and determine the cost, schedule, and quality impact of each change together with the reason for the change. This information should be utilized in the preparation and submission of lessons learned. A systematic method for posting ECNs against the affected documents needs to be established, including criteria for when affected documents need to be revised to incorporate outstanding ECNs.

7.3. Field Change Notices (FCNs)

Field Change Notices are initiated by the construction contractor, and, or the startup testing organization in response to installation or fabrication problems. They constitute a potential violation of configuration management and should be approved by the Authority Having Jurisdiction or Design Authority. A systematic method for posting FCNs against the affected documents needs to be established, including criteria for when affected documents need to be revised to incorporate outstanding FCNs.

7.4. Nonconformance Reports (NCRs)

Nonconformance reports are initiated by the projects construction inspectors and constitute a requirement that the contractor take corrective active to correct a noncompliance. Each noncompliance should be formally tracked to ensure that it is corrected. Each NCR should undergo a root cause analysis to ensure the underlying problem is not repeated. Each NCR should undergo an extent of condition evaluation to determine whether the condition is a one time event or requires a more generic action to prevent recurrence, in which case consideration needs to be given to either revising the underlying requirement document (e.g., specification or drawing), or issuing an ECN or FCN. A systematic method for posting NCRs against the affected documents needs to be established, including criteria for when affected documents need to be revised to incorporate the NCRs. Of special concern are NCRs that allow a one time deviation for the affected documents.

7.5. Contractor and Vender Claims

Contractor and vendor claims should be assessed for validity and compensation recommended as appropriate. All pending claims should be identified as potential sources of contingency draw down and summarized in the project's status reports. Valid claims should be considered for possible inclusion in the Department's lessons learned files.

7.6. As-Built Documents

The decision needs to be made prior to the start of construction activities as to which documents will be required to reflect the as-built condition once the construction and testing activities have been completed.

ATTACHMENTS

REQUIREMENT AREAS THAT HAVE REPEATEDLY PROVEN TO NEED A GREATER DEPTH OF DETAIL OR REFINEMENT

- Safety-class and safety-significant fire protection system requirements relating to:
  - Adequacy of water supplies.
  - Fireproofing of structural steel.
  - Degradation of HEPA filters.
  - Combustible loadings.
  - Fire detection and suppression system activation mechanisms.
- Required analysis of possible hydrogen and flammable gas generation and accumulation.
- Seismic design requirements relating to:
  - Ground motion.
  - Geotechnical investigations.
  - Soil settlement
- Structural engineering requirements relating to:
  - Soil-structure interaction analyses.
  - Load paths for seismic and settlement induced forces.
  - Finite element analysis.
  - Structural computer codes.
- Confinement strategy requirements relating to:
  - Analysis of the adequacy of the confinement barriers.
  - Magnitude of the radiological source term.
  - Models.
- Criticality standard requirements.
- Chemical processing safety requirements.
- Definition, selection, and implementation of quality assurance requirements.

- Requirements relating to the potential for solids settlement in pipes and ducts.
- Requirements relating to the application of lessons learned.
- Requirements relating to assumptions:
    - Basis.
    - Degree of conservatism.
    - Timely verification/confirmation.
- Requirements relating to acceptable calculation tools and techniques.

PROJECT EXECUTION INTERFACES WITH DOE P 450.4

DOE O 413.3A requires that projects be planned, design, and executed using Integrated Safety Management policies and procedures. Integrated Safety Management policies and procedures are specified in other Directives and Rules including DOE P 450.4, *Safety Management System Policy*. Some of the most pertinent interfaces between DOE P 450.4 and this Guide can be seen in the following extracts from DOE P 450.4:

- "Direct involvement of workers during the development and implementation of safety management systems is essential for their success."
- "Personnel shall possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities."
- "Before work is performed … an agreed-upon set of safety standards and requirements shall be established which, if properly implemented, will provide adequate assurance that the public, the workers, and the environment are protected from adverse consequences."
- "Missions are translated into work, expectations are set, tasks are identified and prioritized, and resources are allocated."
- "Applicable standards and requirements are identified and agreed-upon…"
- "…opportunities for improving the definition and planning of work are identified and implemented…"
- "Responsibilities must be clearly defined in documents appropriate to the activity."

PROJECT EXECUTION INTERFACES WITH DOE G 450.4-1B

DOE O 413.3A requires that projects be planned, designed, and executed using Integrated Safety Management policies and procedures. Integrated Safety Management policies and procedures are specified in other Directives and Rules including DOE G 450.4-1B, Volume 1; *Integrated Safety Management System Guide*. Some of the more pertinent interfaces between DOE G 450.4-1B and this Guide can be seen in the following extracts from DOE G 450.4-1B, Volume 1:

- "Integration is especially important for programs and activities with conflicting or competing goals or requirements (e.g., fire protection and criticality safety, or personnel safety and safeguards and security)." (page 6)

- "Other programs, such as those for configuration management and conduct of operations are more appropriately specified at the facility or project level." (page 6)

- "Identify Facility Standards and Requirements." (Figure1, page 8)

- "Identify Activity Standards and Requirements." (Figure 1, page 8)

- "A first step is to translate missions into work requirements in conjunction with the prioritization of budget and resources." (page 10)

- "Individuals responsible for engineering the processes (e.g., weapons assembly and disassembly, nuclear material fabrication and stabilization, criticality experiments, waste storage, hazardous waste cleanup, routine maintenance, pollution prevention, and waste minimization) should work with multidisciplinary teams who have direct responsibility for analyzing hazards, identifying control measures derived from that analysis, and ensuring those measures are effective." (page 11)

- "…managers responsible for individual systems should know where each of their processes interfaces with a process owned by another organization. Responsible managers should then communicate routinely with interfacing managers to assess the efficiency and effectiveness of the process and communicate immediately whenever changes occur that have an impact on one or more interfaces." (page 11)

- "Meaningful management commitment to worker safety requires … ensuring compliance with all applicable requirements and regulations." (pages 11 and 12)

- "Further, for processes involving multiple types of hazards, consideration should be given to the use of worker/management teams with a variety of expertise to ensure that each type of hazard receives informed considerations." (page 14)

- "The exact nature of the activity changes as the safety processes are integrated:

  - first, with the conceptual design, preliminary design, and final design activities;

  - second, with the engineering design and development activities;

- third, with the more traditional integrated safety management activities associated with the physical plant during the construction and operational phases; and

- finally, with the activities to be performed during facility disposition." (page 15)

▪ "Work planning begins the integration of all systems pertinent and necessary to a process, operation, or task." (page 26)

▪ "It is extremely important for DOE and its contractors to formally establish and clearly define the work to be performed, the priority assigned, and the expectations for completion." (page 28)

▪ "Each organizational level (i.e., DOE Headquarters, DOE field element, contractor) should, therefore, establish a method for ensuring a proper balance among competing priorities of the organization (e.g., budget, schedule, safety, quality) …Typically, a senior management review committee or council within DOE or the contractor organization may be established to resolve conflicts, establish priorities, and ensure a balance in resource allocation." (page 31)

▪ "The knowledge, skills, and abilities of the work force should be considered when selecting the form of controls." (page 41)

▪ "The DEAR ES&H clause (48CFR 970.5223-1(b) (6)) and DOE P 450.4 require the integration of environment, safety, and health functions and activities including pollution prevention and waste minimization into work planning and execution. Integration should be evident throughout all organizational functions at all organizational levels from the site to the individual activity." … "Typical site wide processes, procedures, and/or programs that need to be integrated include engineering support, fire protection, emergency preparedness, maintenance, environmental protection, waste management, industrial hygiene, occupational safety, chemical safety, radiological protection, and training." (page 72)

PROJECT EXECUTION INTERFACES WITH DOE G 450.3-3

DOE O 413.3A requires that projects be planned, designed, and executed using Integrated Safety Management policies and procedures. Integrated Safety Management policies and procedures are specified in other Directives and Rules including DOE G 450.3-3; *Tailoring for Integrated Safety Management Applications.* Some of the more pertinent interfaces between DOE G 450.3-3 and this Guide can be seen in the following extracts from DOE G 450.3-3.

- "Designing work entails making decisions about a continuous variety of options and tradeoffs. It is the balance of these options and tradeoffs that determine if a work design will be successful. Many of these tradeoffs are integrally related to tailoring the other elements. They include developing and resolving the work scope, establishing a technical approach, adjusting resources, adapting personnel (experience and expertise), adjusting schedule, and performing tasks sequentially or in parallel to minimize hazards or to optimize the critical work path." (page 8)

- "Too often, formality and documentation are associated, or equated, with budget or cost, even when the work and the hazards are of a routine nature. A better gauge of the need for formal documentation is the complexity of the work…" (page 8)

- "There is a faded management adage that "systems break down at the interfaces." So, too do the benefits of hazards analyses, if no attention is paid to how workers' jobs can affect one another to cause accidents; how juxtapose (either directly connected or nearby) activities or processes can influence one another; how multiple activities or projects within a single facility can adversely affect or be affected by the shared support systems provide by that facility…." (page 10)

PROJECT EXECUTION INTERFACES WITH DOE O 440.1B AND DOE G 440.1-2

Construction safety is not specifically addressed in DOE O 413.3A. It is, however, an inherent part of integrated safety management and the FPD and the IPT need to be cognizant of the following interfaces with DOE O 440.1B, *Worker Protection for DOE (including National Nuclear Security Administration) Federal Employees* and DOE G 440.1-2, *Construction Safety Management Guide for Use with DOE O 440.1*.

- "Construction Project Mangers determine the necessity for requiring dedicated construction contractor safety and health personnel on project workplaces." [DOE O 440.1B, Attachment 1, paragraph1(b)(1)]

- "Construction Project Managers ensure that construction project acquisition documents provide information or reference to existing documentation that describes known hazards to which project workers ma be exposed." [DOE O 440.1B, Attachment 1, paragraph1 (b)(2)]

- "Construction Project Managers ensure that a pre-work safety meeting is conducted with the construction contractor to review project safety and health requirements." [DOE O 440.1B, Attachment 1, paragraph1(b)(3)]

- "Construction Project Managers ensure that the project safety and health plan is approved prior to any on-site project work and that required hazard analyses are completed and approved prior to start of work on affected construction operations." [DOE O 440.1B, Attachment 1, paragraph1(b)(4)]

- "Construction Project Managers ensure that project safety and health plans and hazard analyses are revised, as necessary, to address identified deficiencies in project safety and health performance or changes in project operations, contractors, or personnel. [DOE O 440.1B, Attachment 1, paragraph1(b)(5)]

- Construction Project Managers, through personal on-site involvement and/or formal delegation to support staff … , perform frequent and regular documented on-site reviews of construction contractor safety and health program effectiveness. [DOE O 440.1B, Attachment 1, paragraph1(b)(6)]

- "Construction Project Managers ensure documentation exists for all formal contract actions taken to enforce construction contractor compliance with project safety and health requirements." [DOE O 440.1B, Attachment 1, paragraph1(b)(7)]

- "… to the greatest extent possible, integrate the management of safety and health, both in terms of project personnel and management methodologies, with the management of the other primary elements of construction project performance: quality, cost and schedule."(DOE G 440.1-2, section 1, page 1)

- "… it is the intent of the Order to integrate the safety and health requirements of the Order, to the greatest extent practicable, with the required activities of the project management team otherwise necessary to ensure compliance with the cost, quality, and schedule requirements of the project." (DOE G 440.1-2, section 3, page 2)

- "It is intended that the safety and health requirements of the Order be clearly communicated to the construction contactor through the development and incorporation of appropriate contract language in the project acquisition documents and not simply by reference." (DOE G 440.1-2, section 4.4, page 6)

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